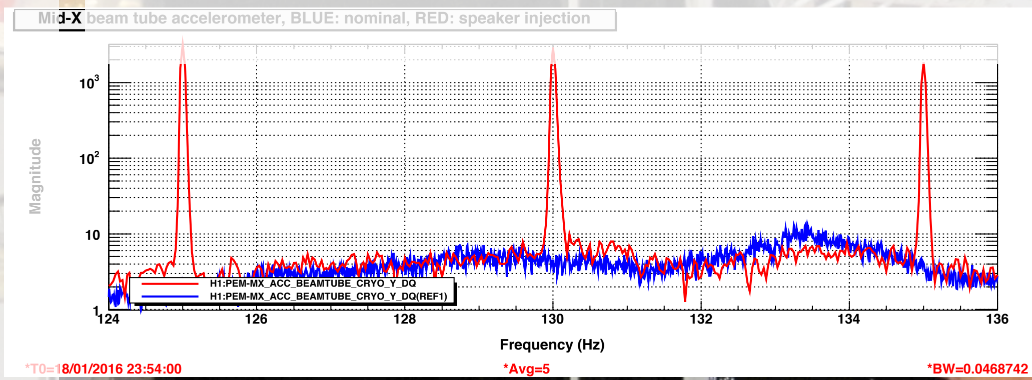
PEM update, March 2016

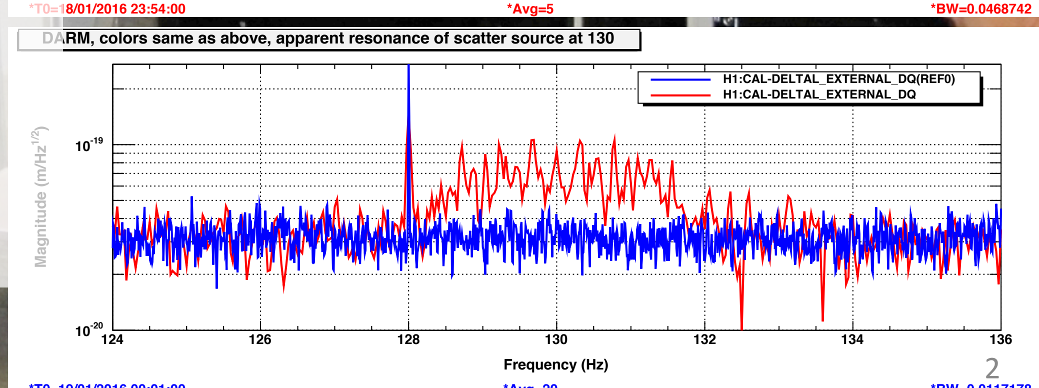
1) PEM system status
2) Status of environmental coupling and suggestions for O2
3) PEM GW vetting past and future
4) Lightning coupling in O1
5) Scattering from ITM eliptical baffle?
6) Microphone proposal to veto beam tube particulate glitches
7) Reducing tilt noise with buried seismometers

Robert Schofield, UO, Anamaria Effler, LLO, Vinny Roma, Jordan Palamos, Dipongkar Talukder, Ray Frey, UO, Terra Hardwick, LSU
LIGO-G1600545

Status of PEM system

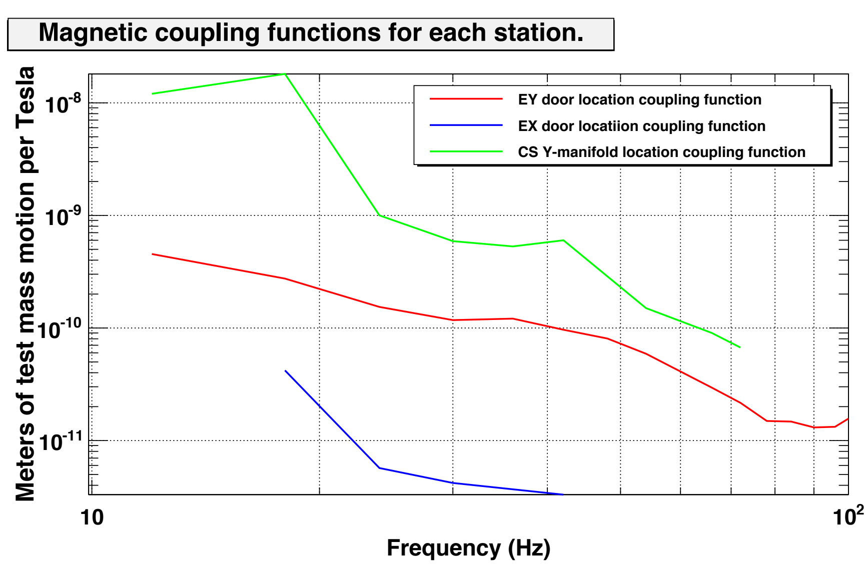
- Virtually all planned sensors have been installed. Some of the sensors have outstanding problems that we are solving.
- High sensitiivity magnetometers will be installed at low-field sites in next few months.
- New microphones to monitor beam tube enclosures?
- PEM injections suggest coverage good, no sensor moves planned.
- New (aLIGO) rack magnetometers have proven very useful in tracking electronic noise sources.
- Mid station acoustic coupling justifies DAQ system there.



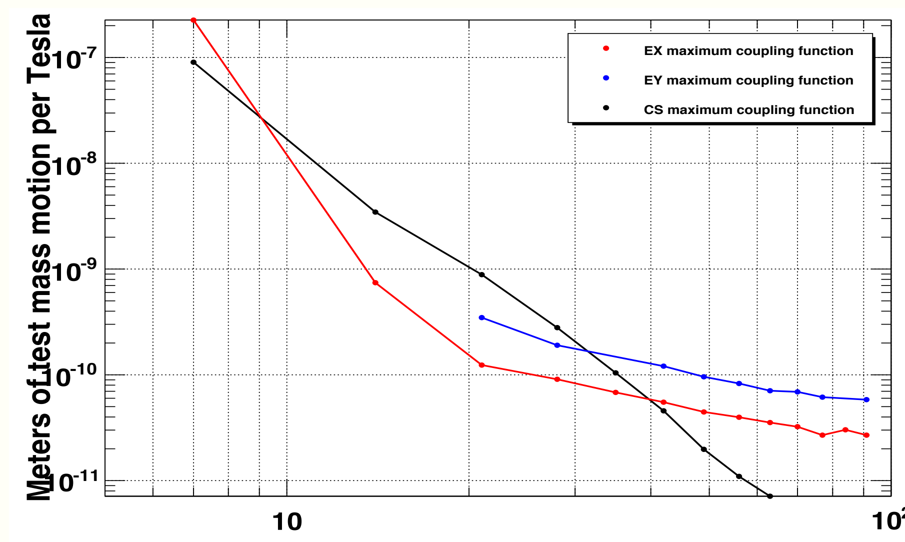


Highest magnetic coupling function at each station

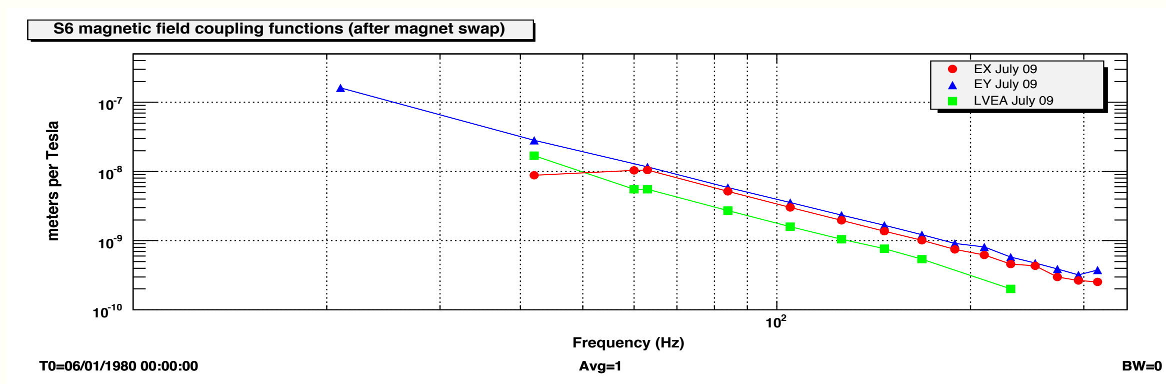
LHO



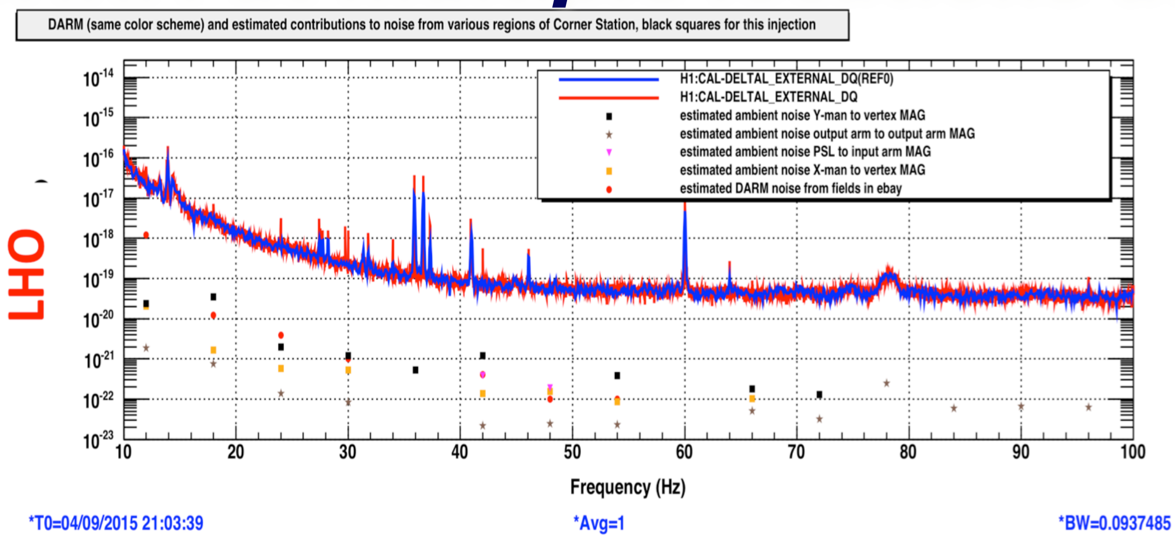
LLO

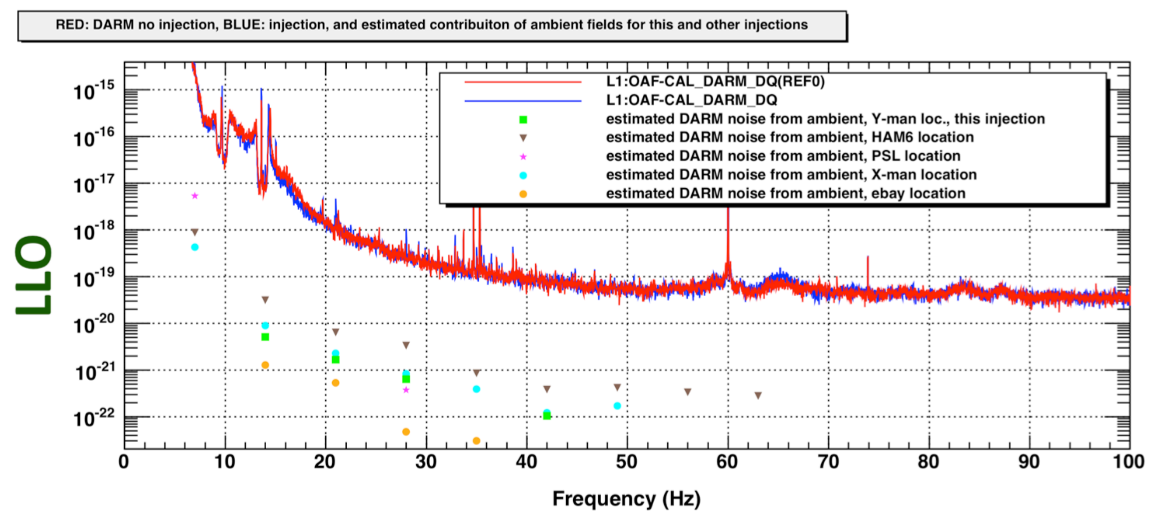


Coupling in initial LIGO was a couple of orders of magnitude higher and followed expected power law for coupling to TM magnets. Now cable coupling dominates.



Contribution of ambient magnetic fields to DARM at multiple locations at CS



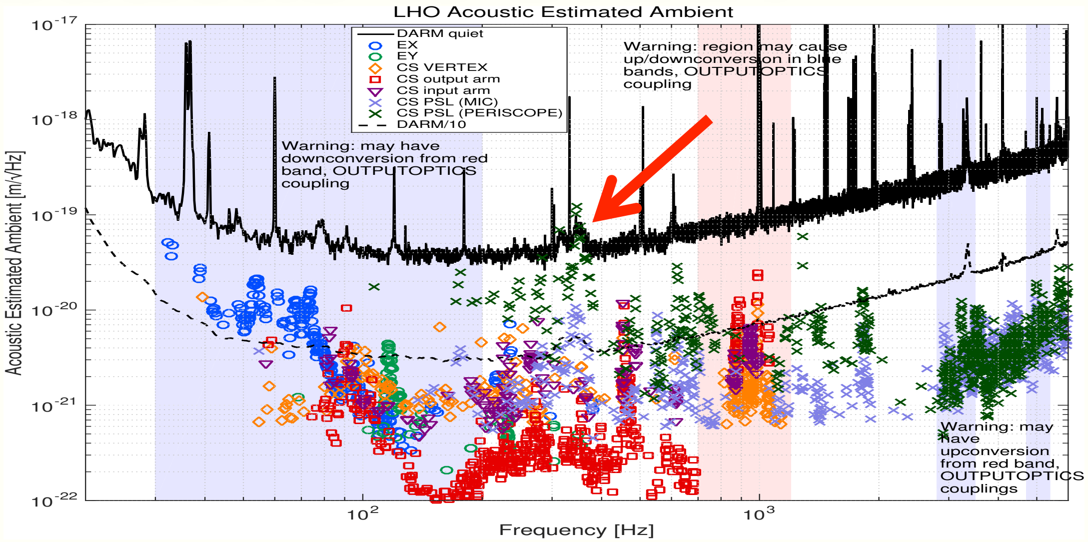


At both LLO and LHO, DARM noise from ambient magnetic fields should be less that 1/10 of noise floor except possibly right around 10 Hz

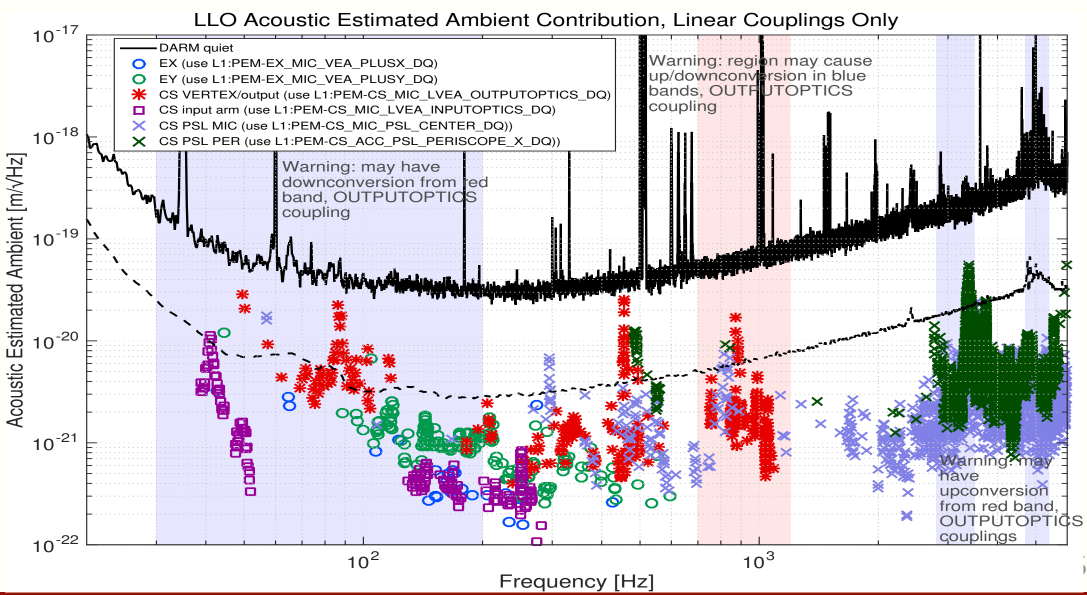
Estimated ambient vibration noise contributions to DARM

Periscope-related peaks are well predicted (arrow) even though prediction is made using single acoustic speaker injections and normal excitation path is from floor up through table.

LHO



LLO



Current vibration coupling

Most important vibration coupling sites, band, and best sensors

LHO

- PSL table, broad band, H1: PEM-CS_ACC_PSL_PERISCOPE_X_DQ
- HAM6, ISI suspension bands, H1:ISI-HAM6_BLND_GS13X,Y,Z_IN1_DQ
- HAM2, ISI suspension bands, H1:ISI-HAM2_BLND_GS13X,Y,Z_IN1_DQ
- BS, 40-70 Hz with upconversion, H1:HPI-BS_BLND_L4C_X,Y,Z_IN1_DQ

LLO

- PSL table, broad band, L1: PEM-CS_ACC_PSL_PERISCOPE_X_DQ
- HAM6, ISI suspension bands, L1:ISI-HAM6_BLND_GS13X,Y,Z_IN1_DQ
- HAM1, 10-20 Hz H1:ISI-HAM2_BLND_GS13X,Y,Z_IN1_DQ
- HAM5, 455 Hz, H1:ISI-HAM2_BLND_GS13X,Y,Z_IN1_DQ

While vibration coupling probably wont be limiting in O2, it will be within a factor of 2 of the DARM floor in some ISI suspension bands and the PSL without further improvements.

PEM-related improvements suggested for O2

1) Reduce jitter coupling at LHO. TCS?

2) Damp HAM6 (and possibly other HAMs) blade springs and flexures.

~~3) More injections to better understand 80-90 and 455 Hz coupling at LLO~~

~~4) Find and fix the high acoustic coupling at LHO EX, scattering?~~

~~5) Mitigate the high magnetic fields around 10 Hz in the LHO ebay.~~

6) Find vibration coupling site at BS

7) Use buried external seismometers to reduce wind tilt problems

8) Check transfer function of OMC suspension at 900 Hz

9) Monitor beam tube stick slips that could produce particulate glitches.

PEM vetting of GW candidates
past and future

I. Primary sensors of environmental coupling

1. Status of sensors: were they working and are they properly monitored by event detectors ?

a. Were the channels functioning properly?
Examination of spectra by multiple experts > LIGOCam only

b. Are malfunctioning channels a coverage issue?
Expert input > Expert input, filtered by most important channel list

c. Special channel checks (e.g. radio)
Direct tests > rely on pre-run PEM injections

d. Are channels being checked by glitch detectors and are the config files OK?
Direct checks by PEM experts (to check for, e.g. monitoring up/down conversion) > once a run check

PEM vetting of GW candidates
past and future

I. Primary sensors of environmental coupling (continued)

2. Coverage: would primary sensors detect every environmental signal that can influence IFO?
   Established by PEM injection > unchanged

3. Events in sensors: were any environmental signals loud enough to reach amplitude of candidate in DARM?
   Hand run of Omega Scan on band of event (and up/ downconversion bands). Hand calculate DARM level for all PEM Omega Scan triggers using results from PEM injections. >
   Automatic calculation using coupling functions stored at PEM.LIGO.ORG.

PEM vetting of GW candidates *past* and *future*

II. Redundant checks of global environment

1. Global electromagnetic environment

Checks of many outside observatories > rely on our own sensors except for special cases e.g. detection of new or unmodeled waveforms

III. Other intersite correlation issue

1. Synchronized electronics

Relied on arguments not checks

> like to check random pairs of channels using the assumption that nothing special about DARM for DAQ system.

IV. Arguments provided against specific sources (risers etc.)

> only in special cases.

Lightning Coupling Update

(prompted by p~1e-4 coincidence with GW150914)

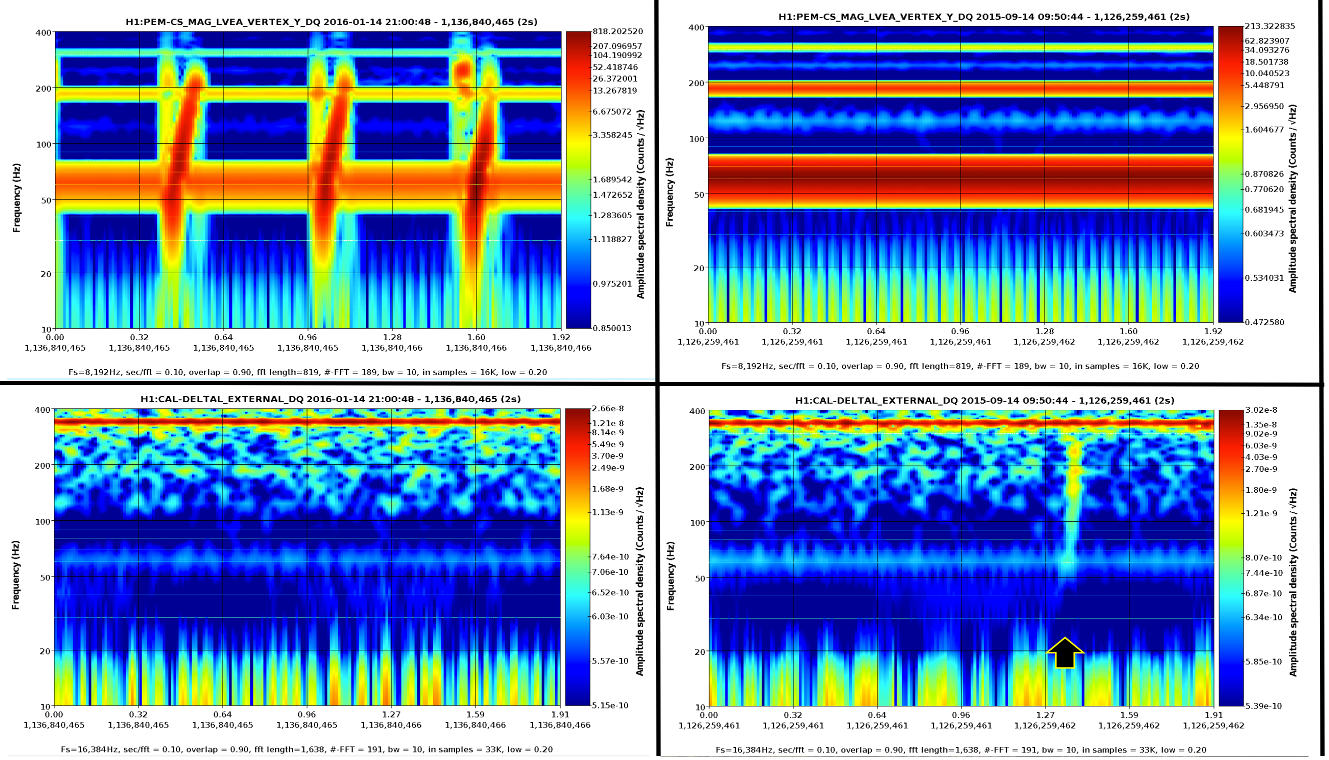
Magnetic fields from the Burkina Faso strike, were at least 3 orders of magnitude too small to produce an event in DARM.

Magnetic chirps (vertical structures, top plot), injected at maximum amplifier settings, do not show on gravitational wave channel (bottom plot). Note that magnetic injection is about 1000 times magnetometer background.

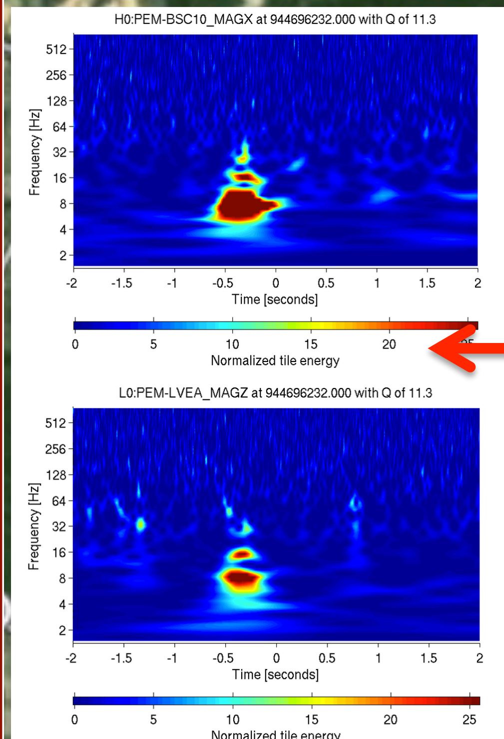
GW150914: nothing seen in magnetometer (top), strong signal in gravitaional wave channel (bottom). Horizonal magnetometer bands are produced by the 60 Hz power grid.

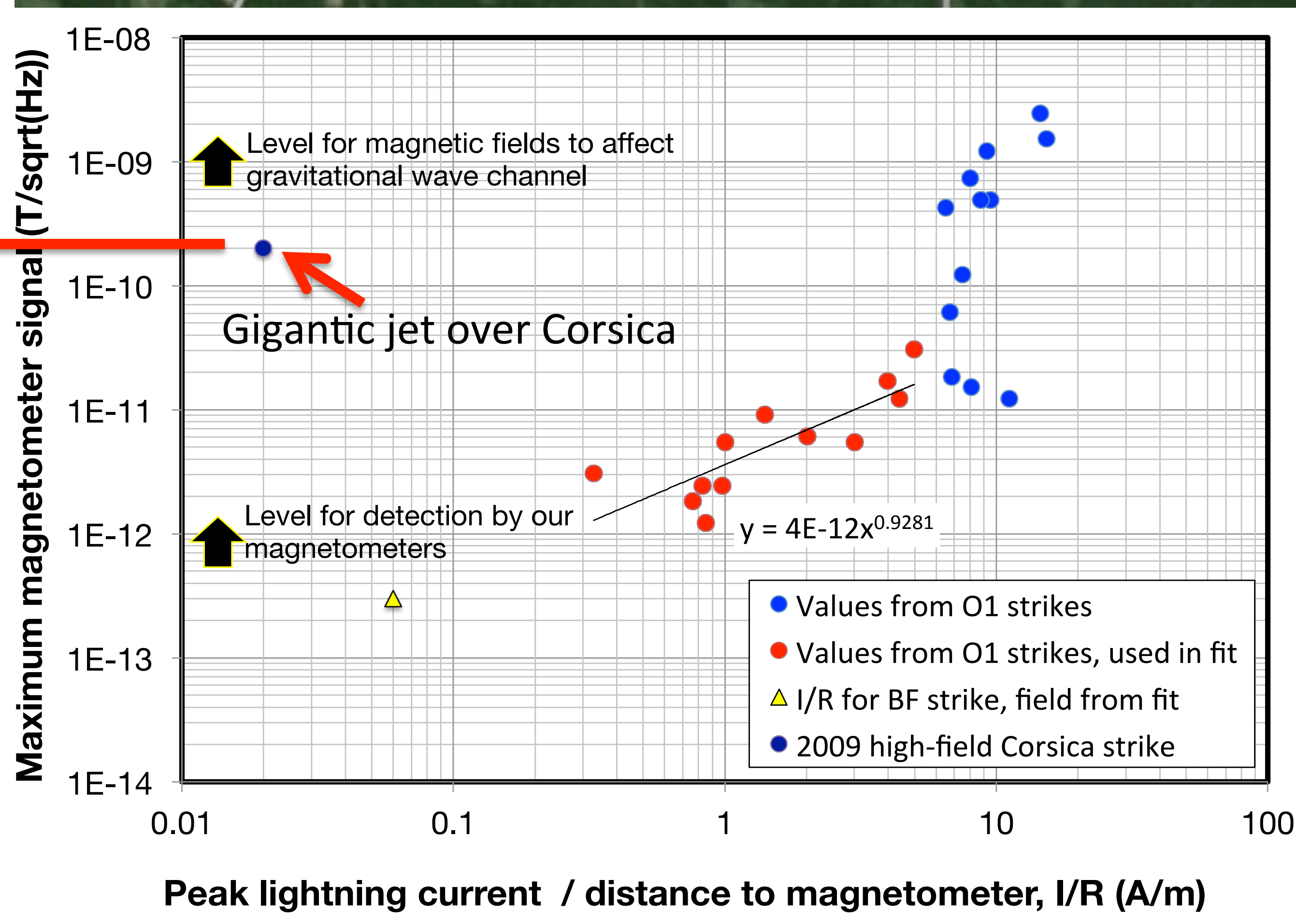
Vertex magnetometer

Gravitational wave channel

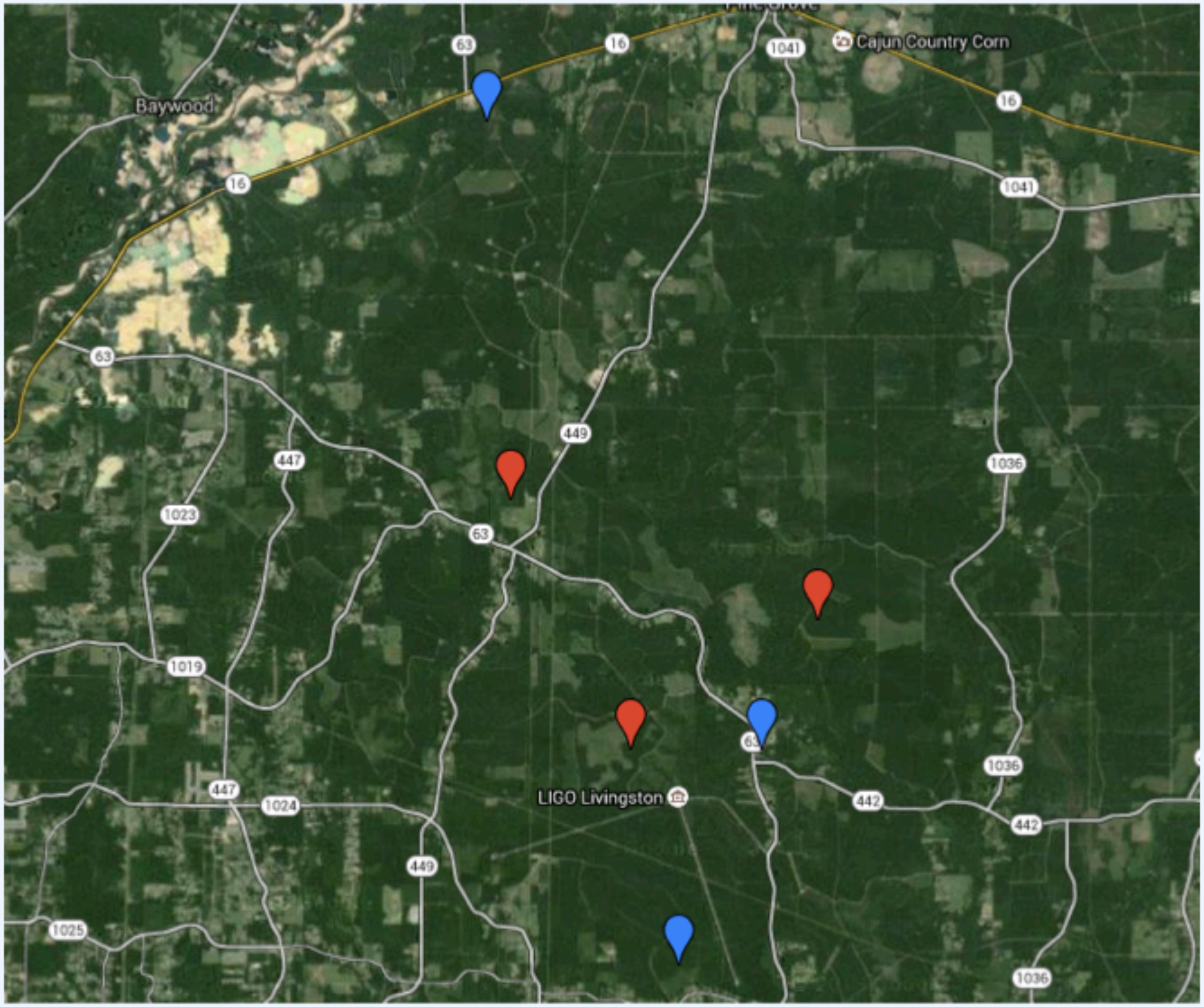


Magnetic field at LLO from lighting

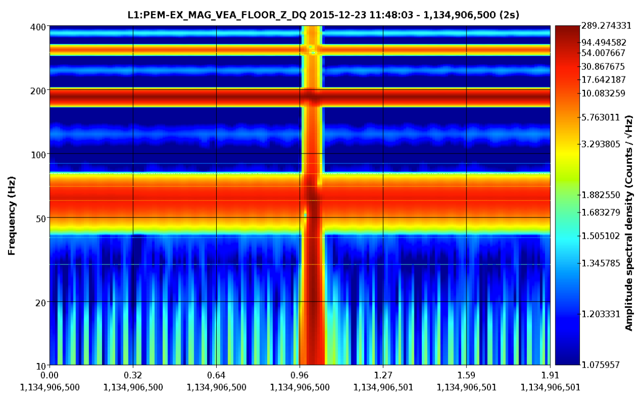
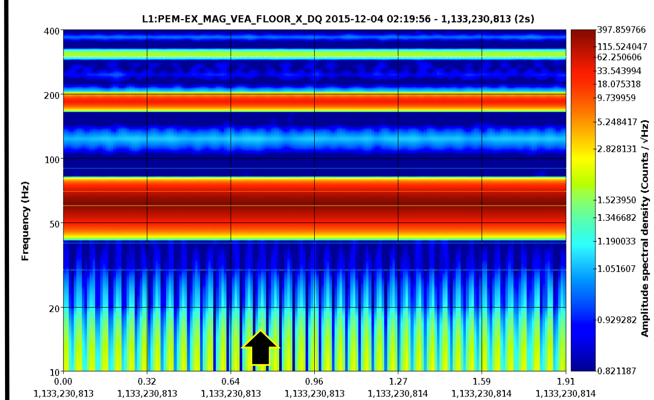
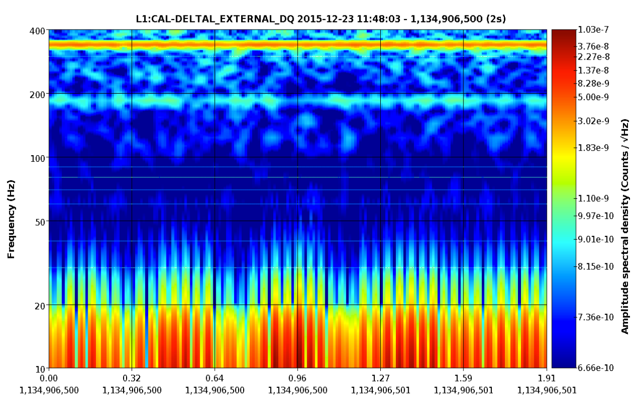
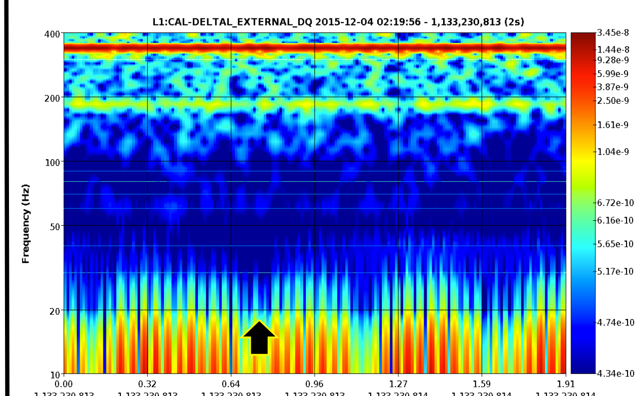




High and low-field strikes (for I/R) near LLO



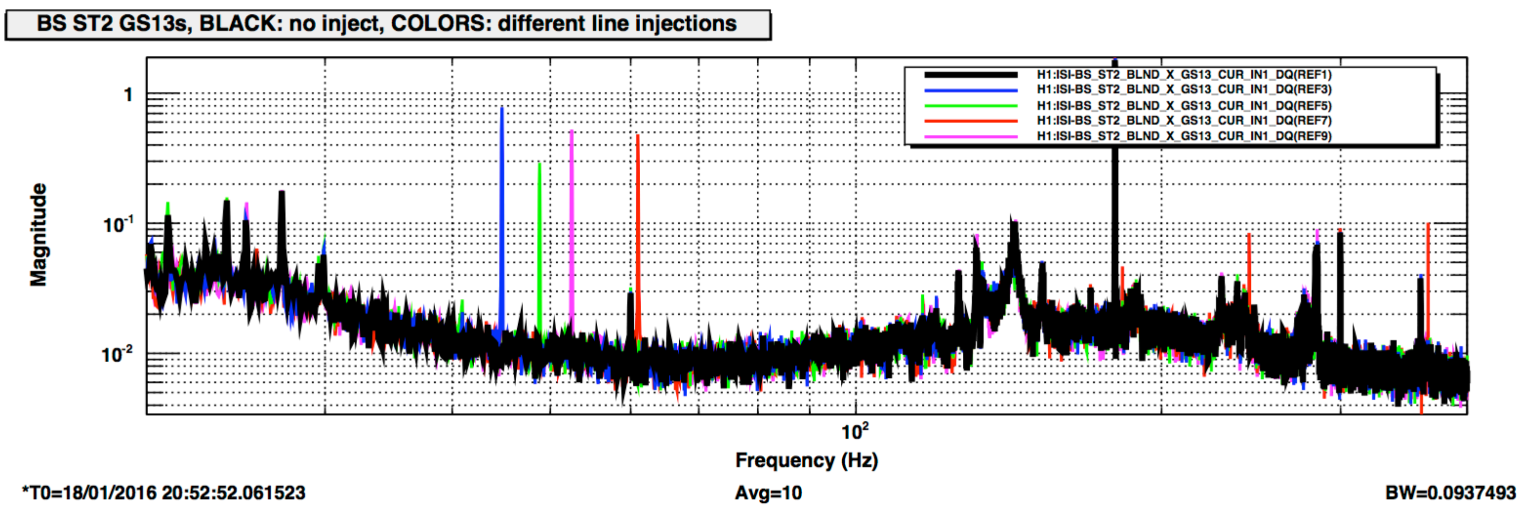
11 US strikes in Dec. 2015 with higher I than Burkina Faso and working IFO: no events

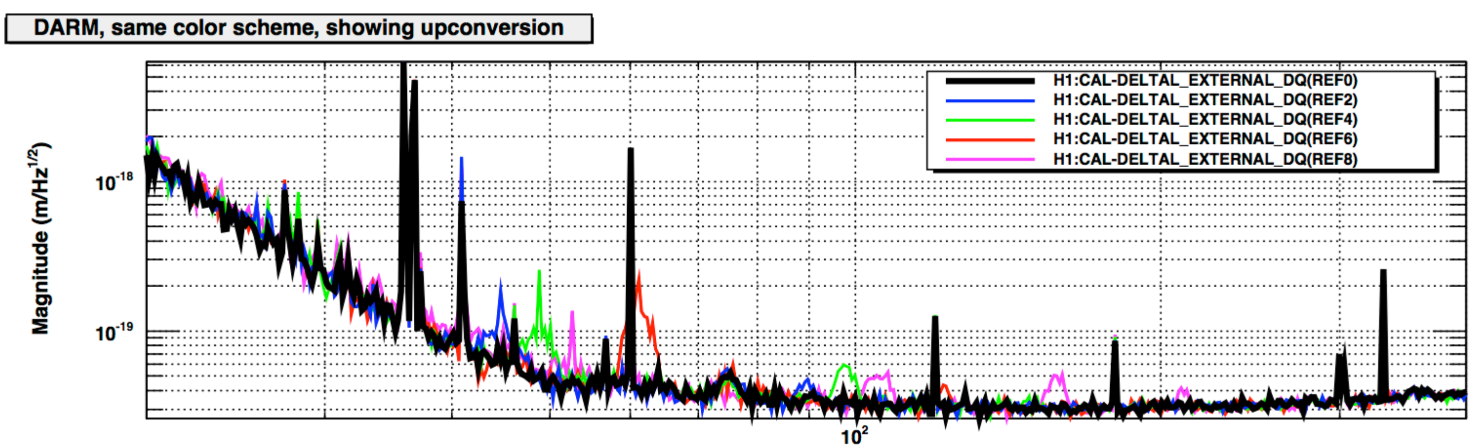
	Lightning with highest I/R value (I: peak current, R: distance to magnetometer) in US in Dec. 2015: I = 241 kA, R = 15 km, I/R = 16 A/m. Seen only in magnetometer	Lightning with highest I in US in Dec. 2015, I = 734 kA, R=1440 km, I/R = 0.51 A/m (for comparison, the Burkina Faso strike was: I = 504 kA, R= 9000 km, I/R = 0.06 A/m). Not seen in magnetometer or GW channel
Vertex magnetometer		
Gravitational wave channel		

Fs=8,192Hz, sec/fft = 0.10, overlap = 0.90, fft length=819, #-FFT = 191, bw = 10, in samples = 16K, low = 0.20

Fs=16,384Hz, sec/fft = 0.10, overlap = 0.90, fft length=1,638, #-FFT = 191, bw = 10, in samples = 33K, low = 0.20

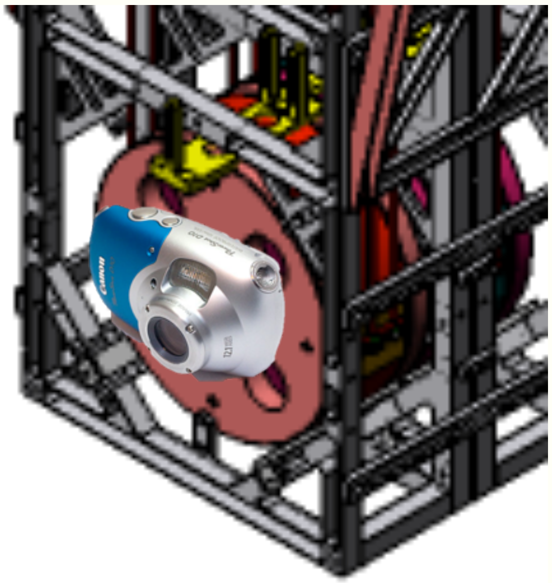
Shaker on most chambers; highest upconversion at BS



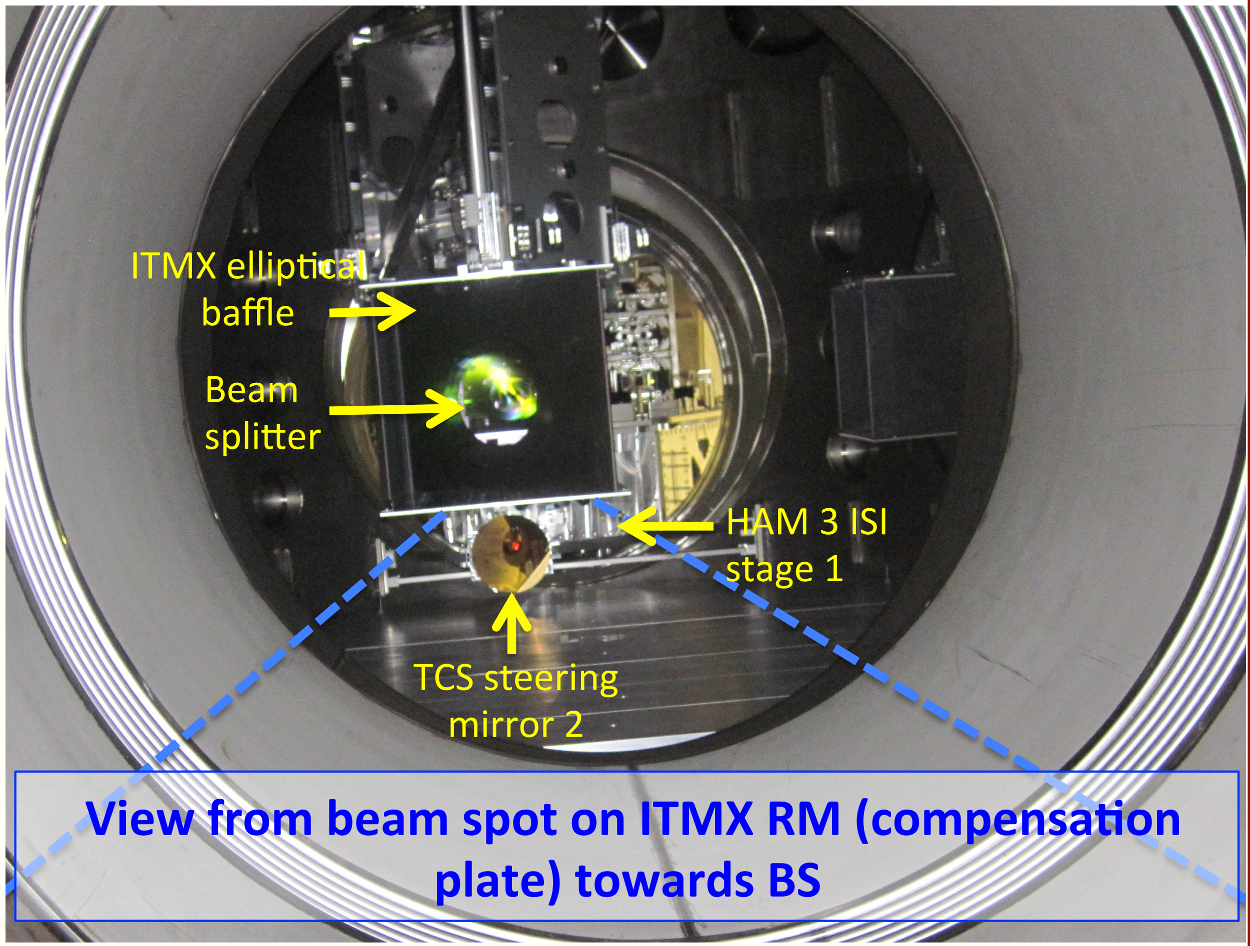


Large side bands suggest scattering

What reflective surface might move in light when BS isolation shaken?

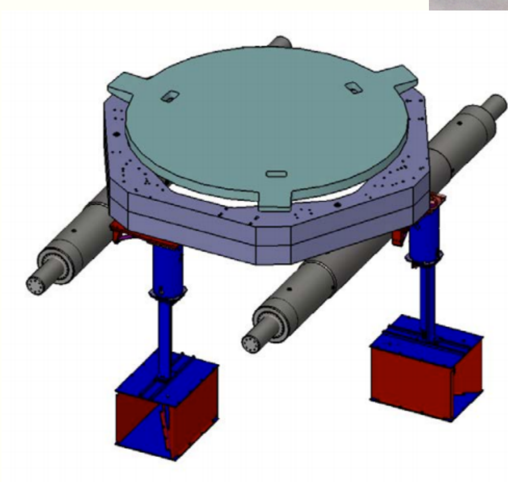


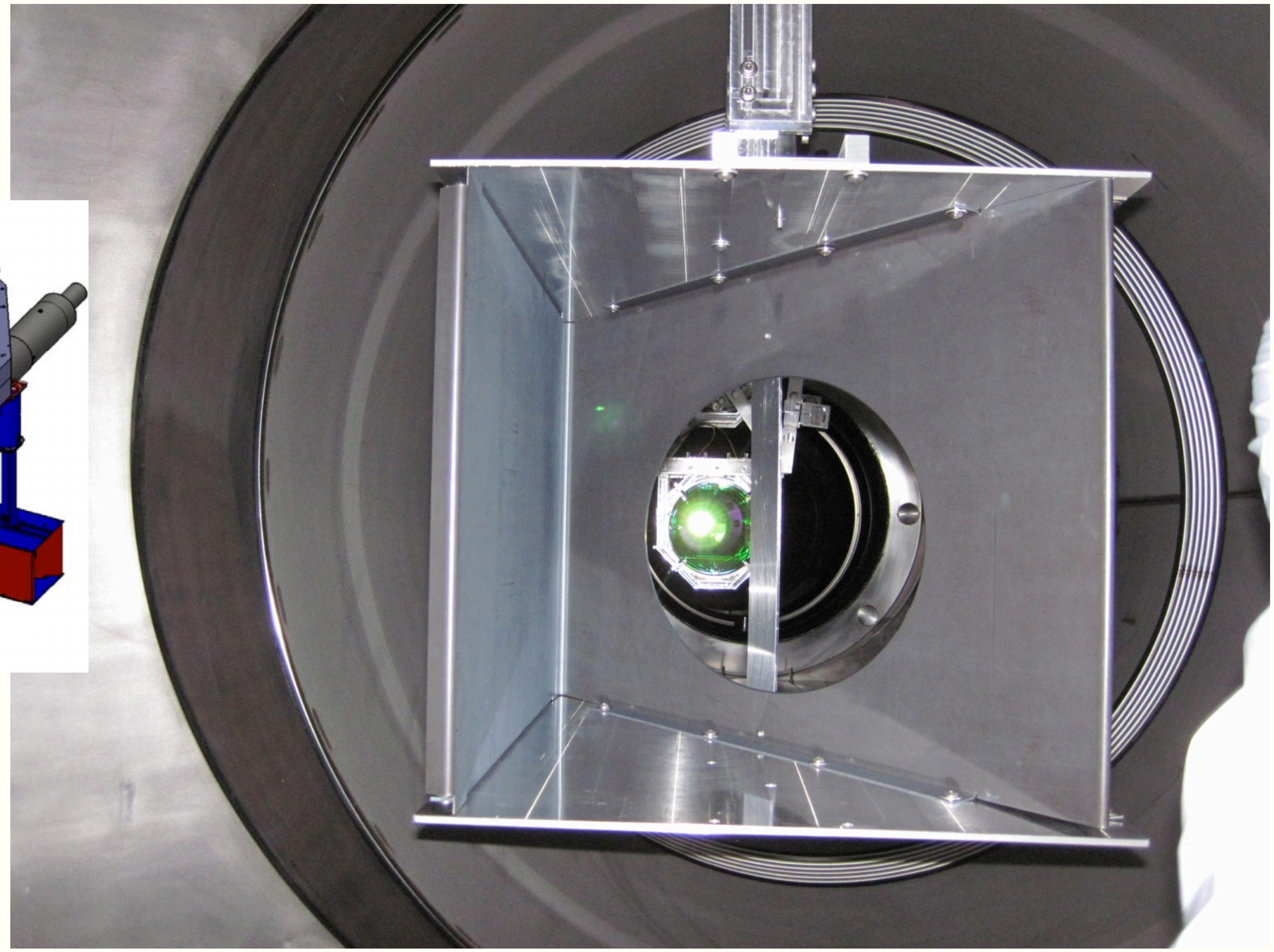
Beam spot view:
camera with flash near lens placed as near as possible to beam spot to observe any surfaces that retro-reflect light scattered from beam spot



View from beam spot on ITMX RM (compensation plate) towards BS

What might move in light when BS isolation shaken?

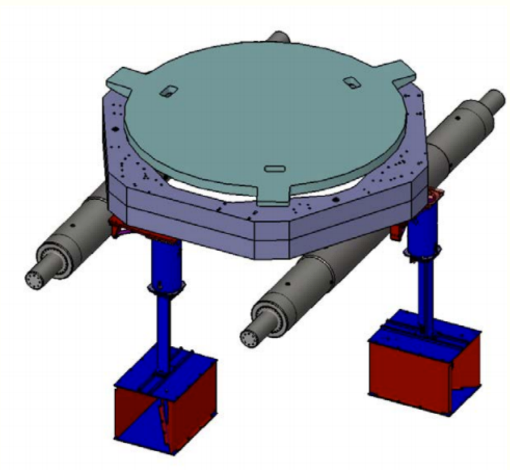


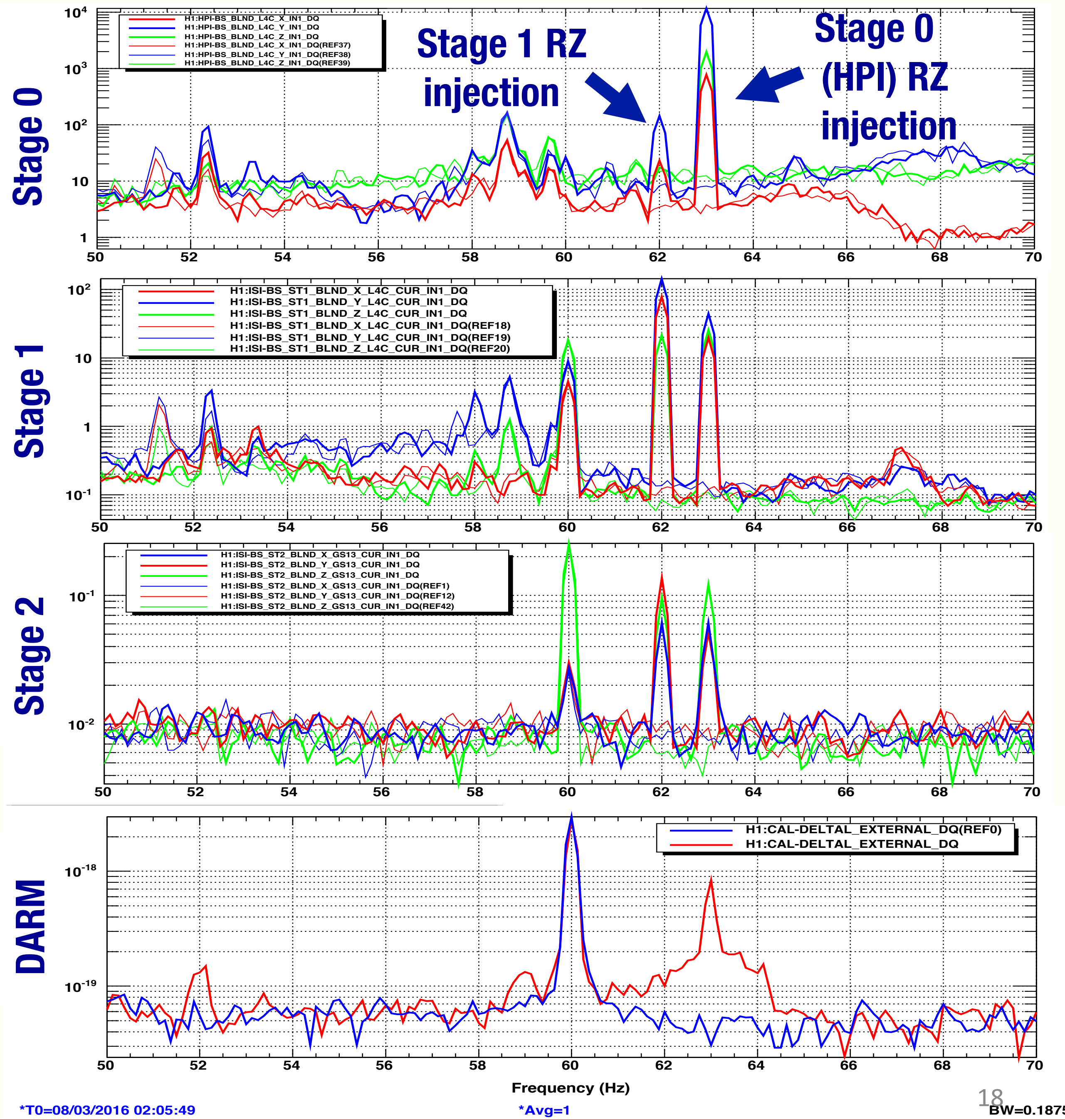


View from BS beam spot towards ITMY

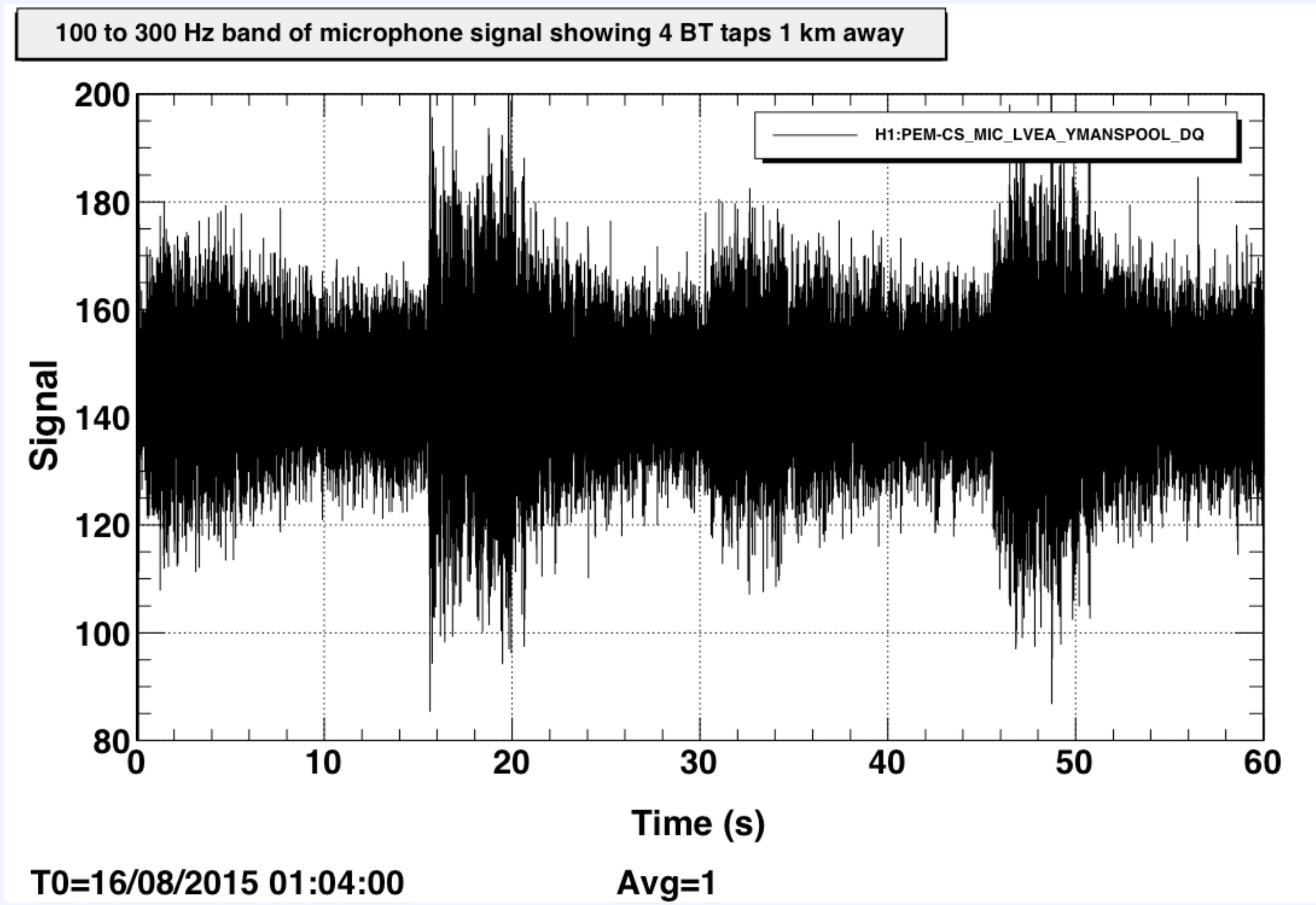
BS SEI injections

Large coupling to DARM for Stage 0 RZ injections but not for Stage 1. Consistent with scattering from ITM eliptical baffle(s), attached to Stage 0.





Proposal: microphones to veto potential beam tube particulate glitches



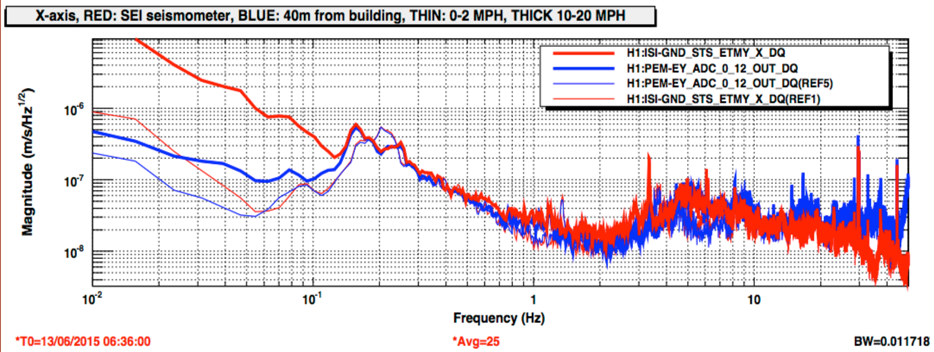
16 beam tube (BT) enclosure microphones could likely detect BT stick-slip events, that were strong enough to have a high probability of producing particulate glitches, anywhere on the BTs.

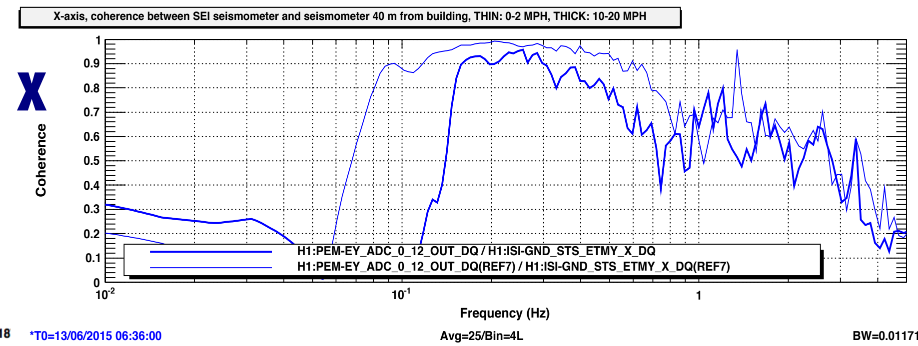
Buried seismometer to reduce tilt noise and improve locking in wind

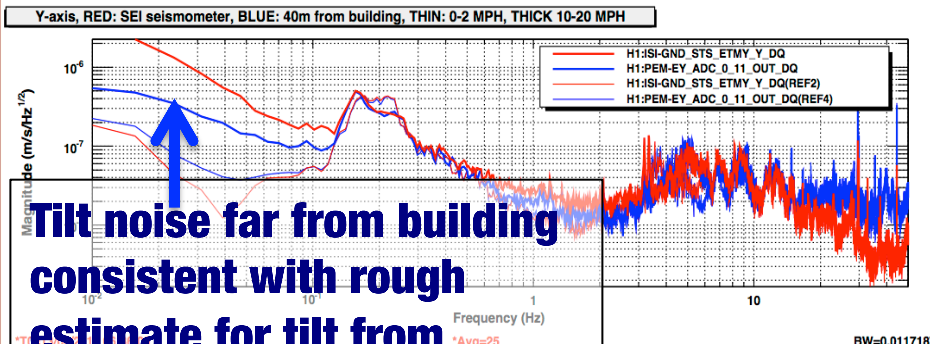
The signals we want to correct for (e.g. microseismic peak) are mostly far field and do not attenuate rapidly with distance from the building. The tilt noise is produced locally, near field, and attenuates rapidly with distance from the building.

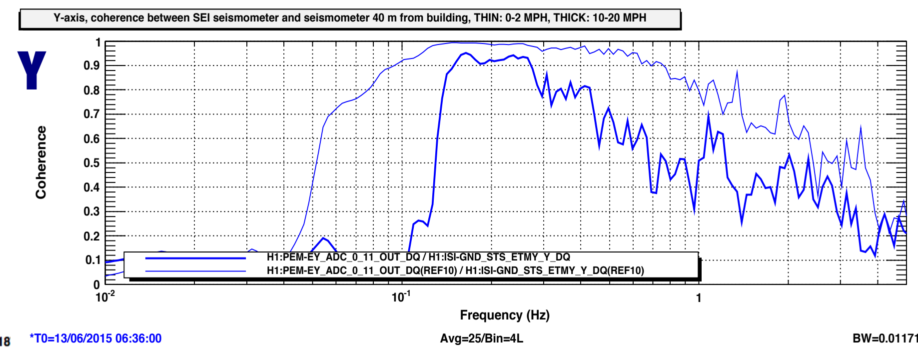
40m +X of EY, 15 MPH

RED: building seismometer, BLUE: buried seis. or coherence, THICK: 15 MPH, THIN: 1.5 MPH

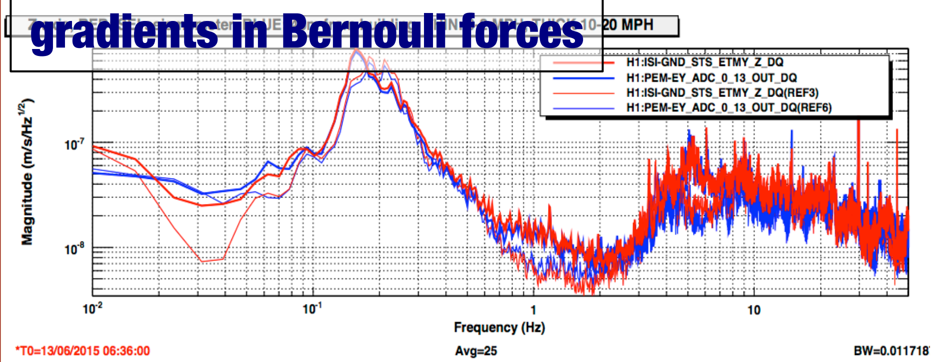


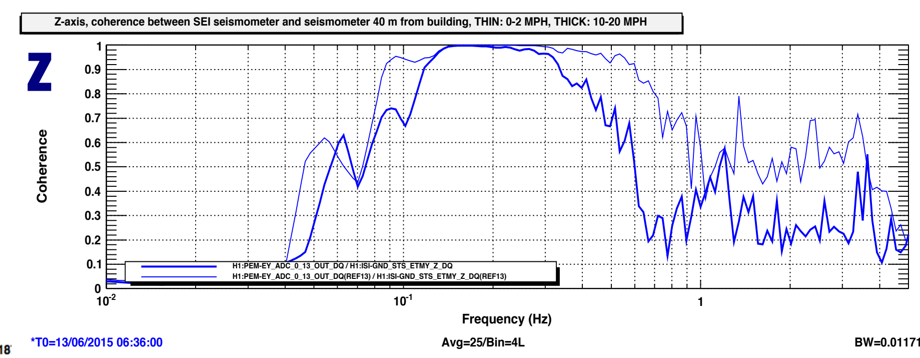






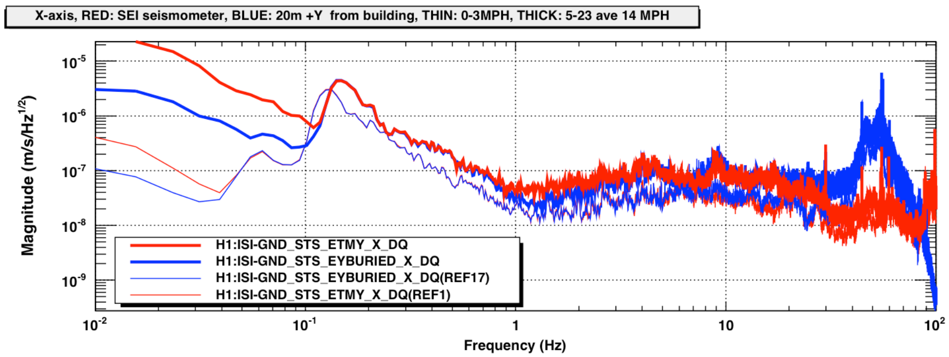
Tilt noise far from building consistent with rough estimate for tilt from gradients in Bernoulli forces

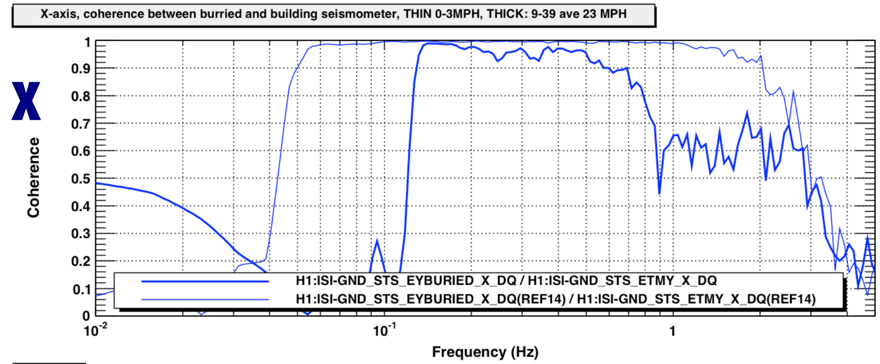


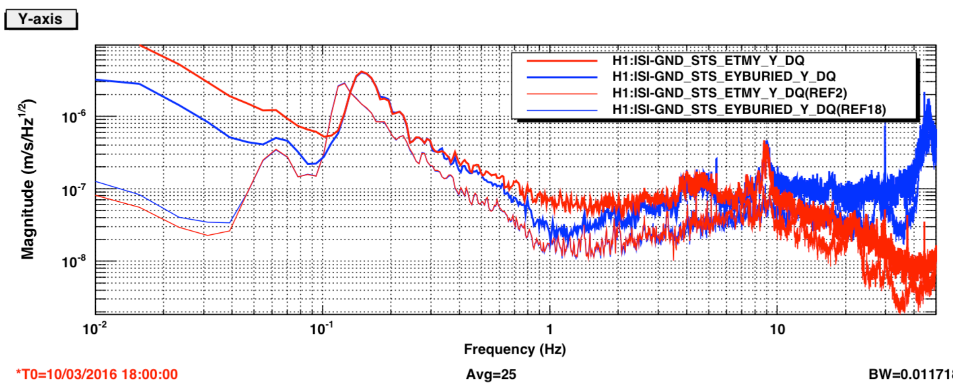


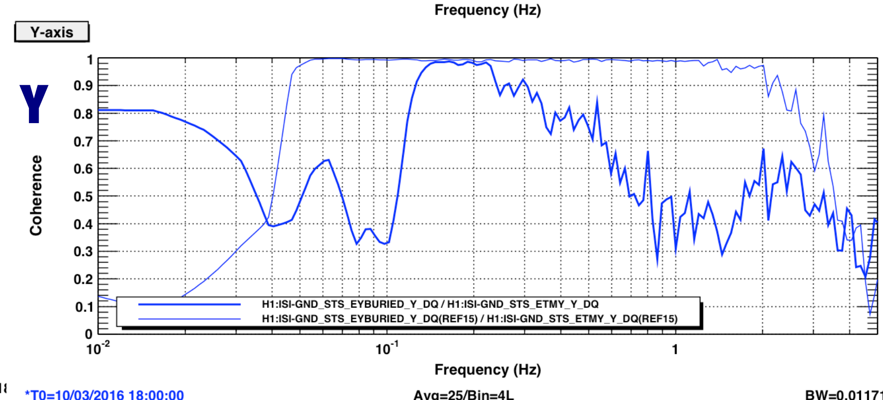
20m +Y of EY, 14 MPH

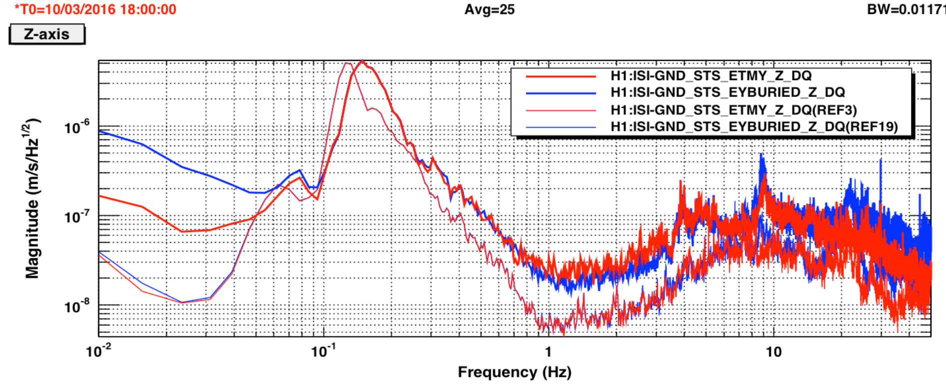
RED: building seismometer, BLUE: buried seis. or coherence, THICK: 14 MPH, THIN: 1.5 MPH

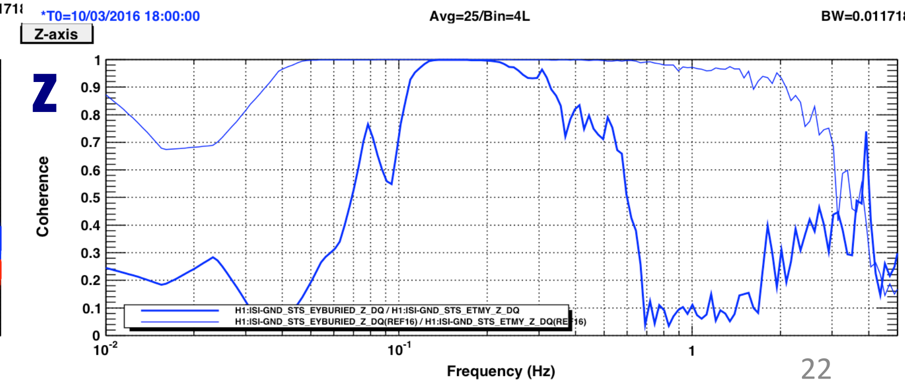






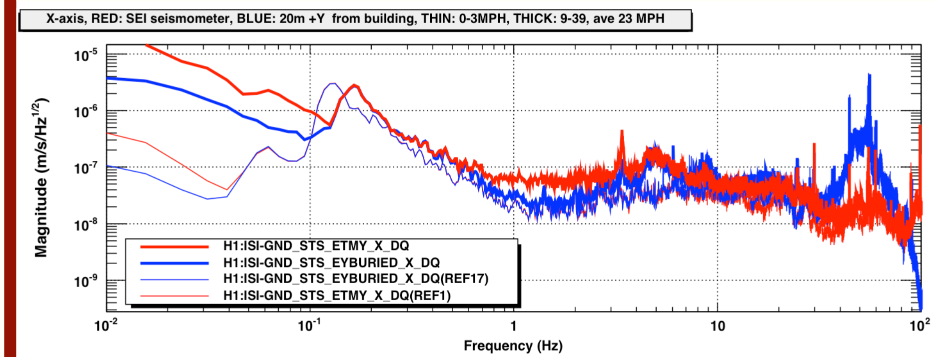


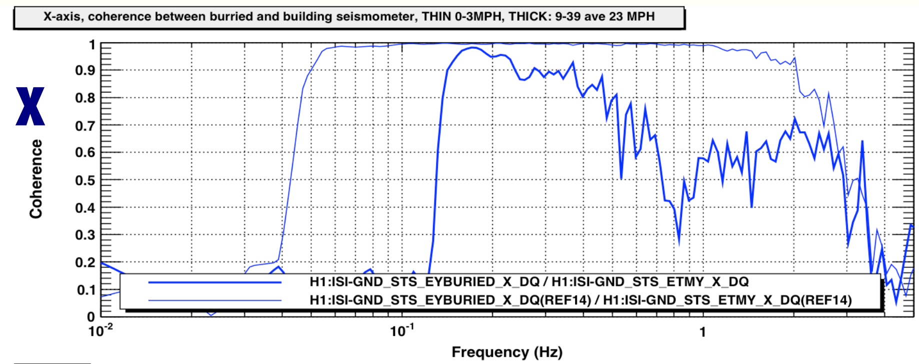


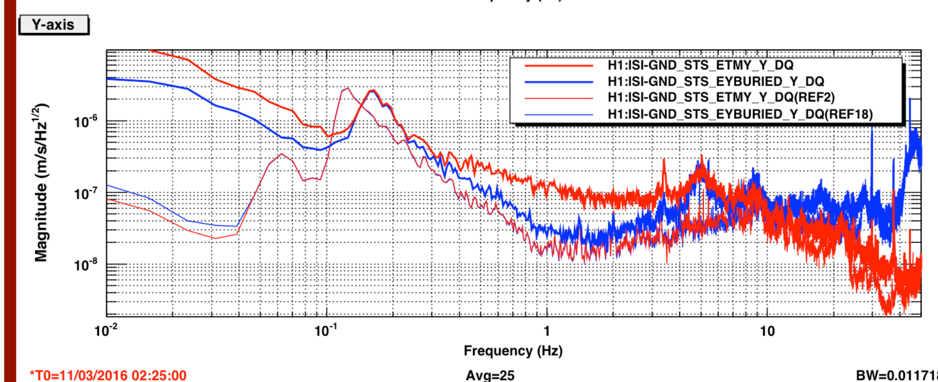


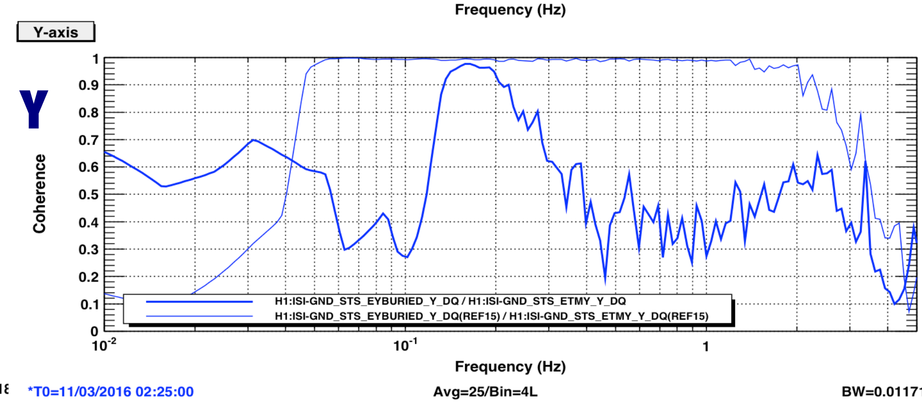
20m +Y of EY, 23 MPH

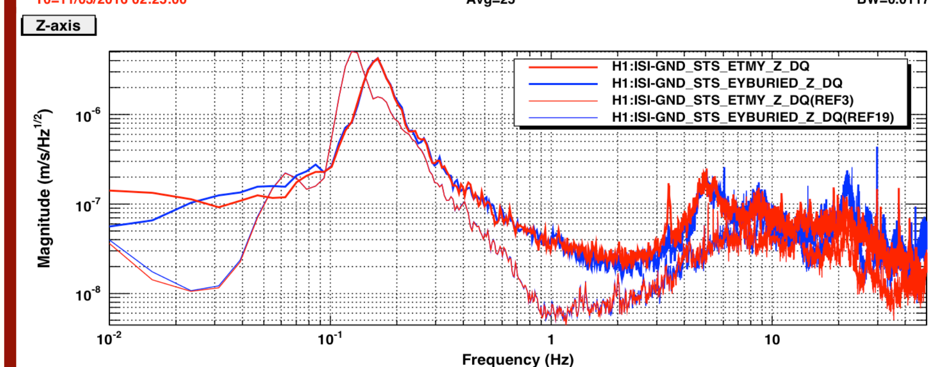
RED: building seismometer, BLUE: buried seis. or coherence, THICK: 23 MPH, THIN: 1.5 MPH

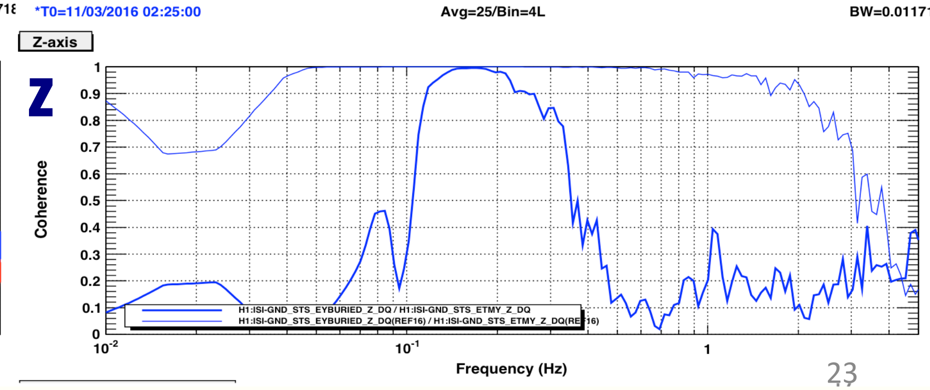




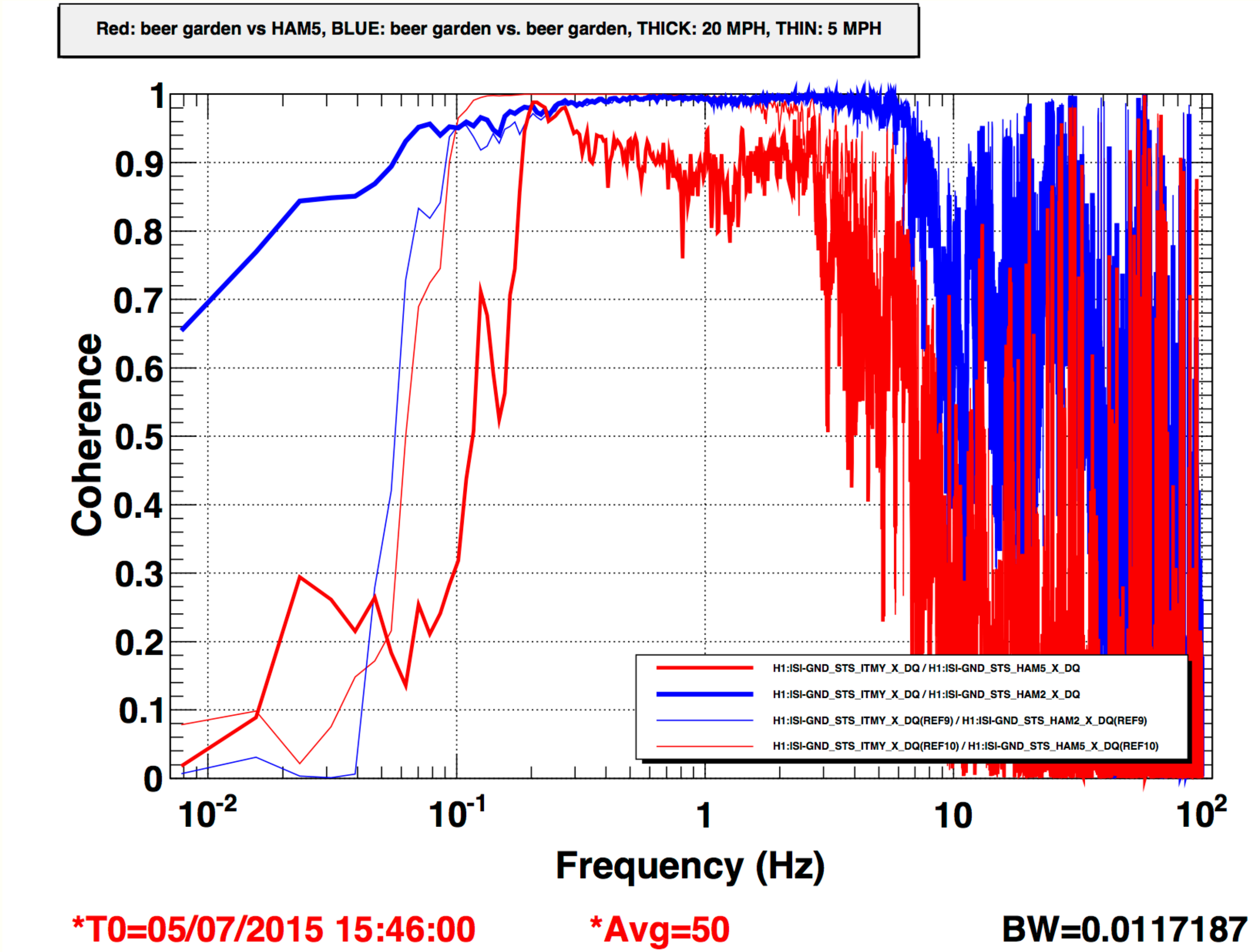






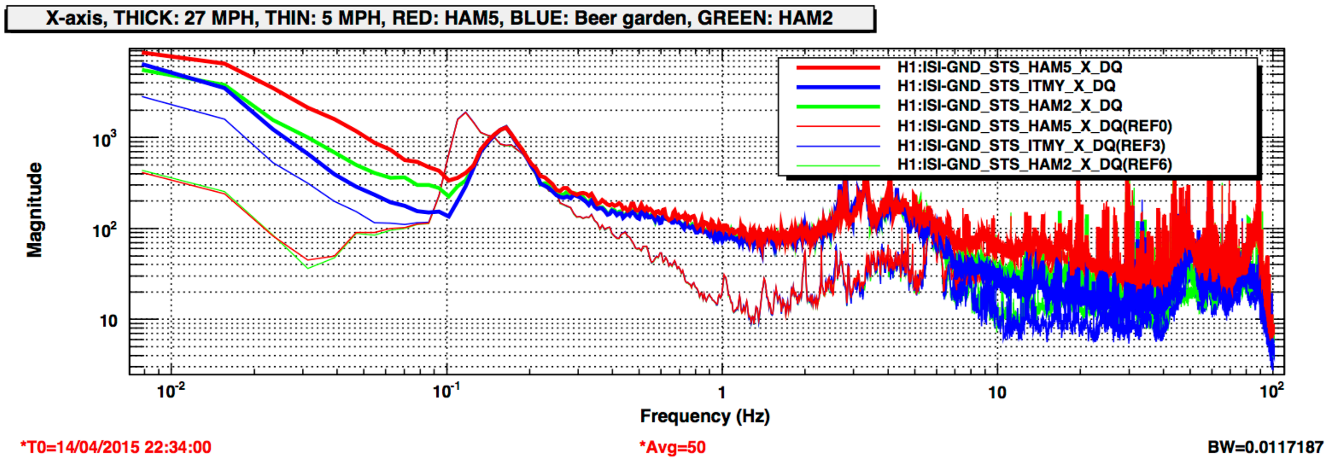


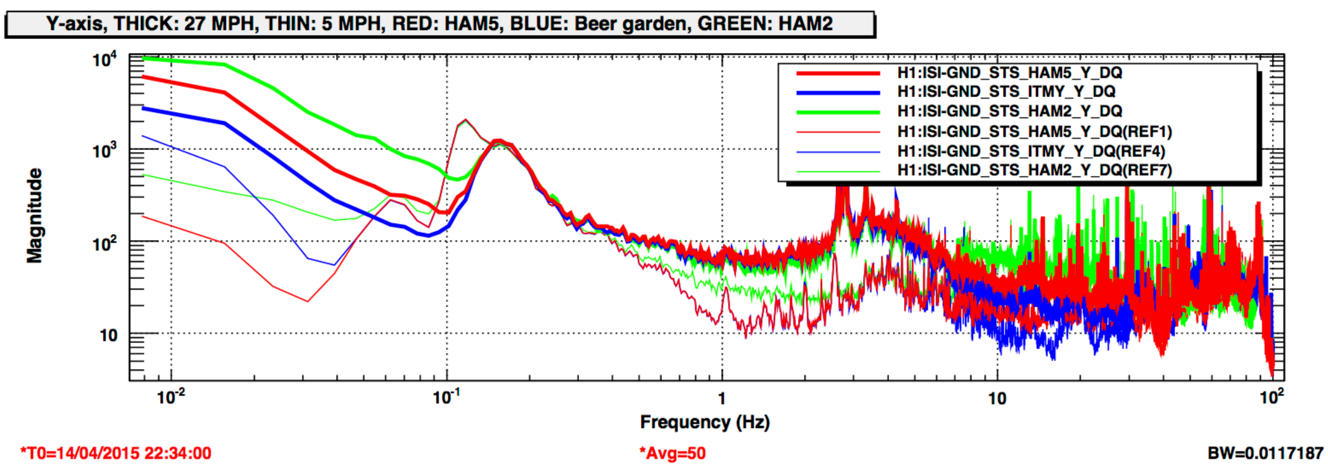
0.1 Hz tilt noise incoherent over 20m



Tilt noise is very local

lower in beer garden (blue) than at HAM5 or 2





PEM update, March 2016

1) PEM system status
2) Status of environmental coupling and suggestions for O2
3) PEM GW vetting past and future
4) Lightning coupling in O1
5) Scattering from ITM eliptical baffle?
6) Microphone proposal to veto beam tube particulate glitches
7) Reducing tilt noise with buried seismometers

Robert Schofield, UO, Anamaria Effler, LLO, Vinny Roma, Jordan Palamos, Dipongkar Talukder, Ray Frey, UO, Terra Hardwick, LSU